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AFOEHL REPORT 90-043EH00542DXX



Ergonomics and Radiation Effects from Video Display Terminals and Workstations

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April 1990

Final Report



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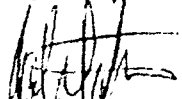
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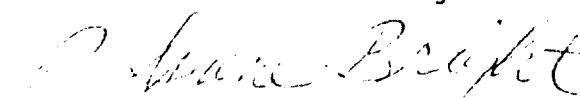
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REPORT DOCUMENTATION PAGE			Form Approved OMB No 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</small>				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE April 1990	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE Ergonomics and Radiation Effects from Video Display Terminals and Workstations.		5. FUNDING NUMBERS PR		
6. AUTHOR(S) P. DIANE BRIGHT, Capt, USAF, BSC PENNY L. FRENCH, MSgt, USAF NOEL D. MONTGOMERY, 1Lt, USAF, BSC				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AF OEHL/EHE/RZ BROOKS AFB TX 78235-5501		8. PERFORMING ORGANIZATION REPORT NUMBER 90-043 EH00542DXX		
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A		10. SPONSORING / MONITORING AGENCY REPORT NUMBER N/A		
11. SUPPLEMENTARY NOTES SUPERSEDES USAFOEHL REPORT #85-059RN111BEJ				
12a. DISTRIBUTION / AVAILABILITY STATEMENT UNLIMITED, approved for public release		12b. DISTRIBUTION CODE N/A		
13. ABSTRACT (Maximum 200 words) This report is written in response to questions from the field concerning the health problems related to video display terminals (VDT). A literature search was conducted of the most current information regarding ergonomics and radiation. This report presents information on the ergonomics of the VDT workplace, suggested exercises to relieve stress, and addresses the radiation aspects and recommendations for use of the VDTs.				
14. SUBJECT TERMS Ergonomics, Radiation		15. NUMBER OF PAGES 29		
		16. PRICE CODE		
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT Unclassified	

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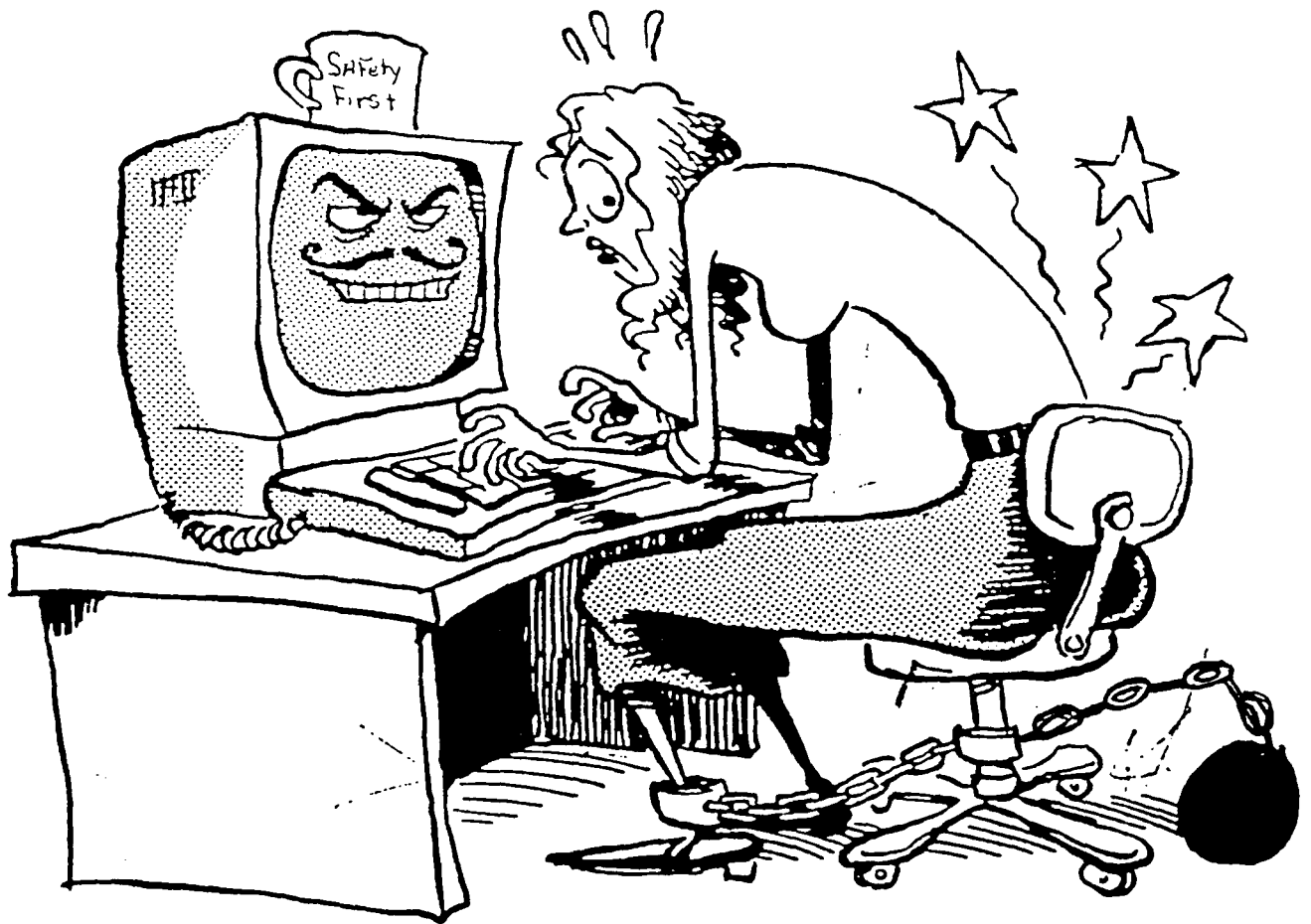
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First she requested a better work station now she wants
"User Friendly"!

PREFACE

This report is written to provide the latest information on the ergonomics and radiation aspects of video display terminals. The first chapter covers the ergonomics using a problem solution format. The second chapter describes the principles of operation, basic bioeffects and radiation physics of video display terminals.

Research in these areas can lead to controversial and sometimes conflicting results. We have tried to provide the most current data. Questions concerning ergonomics should be directed to the Environmental Health Branch at AUTOVON 240-2063. Those concerning radiation should be directed to Radiation Services Division at AUTOVON 240-3486 at the AF Occupational and Environmental Health Laboratory.

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CHAPTER I

ERGONOMICS AND HEALTH PROBLEMS ASSOCIATED WITH VIDEO DISPLAY TERMINALS

I. INTRODUCTION

A. Purpose: This chapter discusses the health problems associated with video display terminals (VDTs) in the workplace. Changes can be made to reduce physical as well as mental stress and to improve worker productivity.

B. Background: The word ergonomics comes from the Greek words "ergo" (work) and "nomos" (laws) and it means a systematic approach to the problems of fit between individuals, their tools and the environment. The technology of work design is based on the human biological sciences (anatomy, physiology, and psychology) and is frequently overlooked in the office workplace. Physical ergonomic deficiencies refer to a poor relationship between the physical design of the workplace and human physical capabilities. Health related problems can result when these deficiencies exist in the VDT workplace. Ergonomics is a major occupational safety and health issue of the 1990s.(8)

C. Scope: The problems experienced by VDT users and how they can be corrected will be discussed. The most frequent complaints are eyestrain, musculoskeletal aches (neck and shoulder discomfort, backache, leg pain, arm pain and wrist pain), and psychological strain to include fatigue, tension and anxiety. It is important to establish the best workplace conditions for VDT users, thus minimizing stress and increasing the quality of performance.

II. DISCUSSION

A. Eyestrain: Eyestrain associated with VDT use is caused by excessive physical adjustments on the eye. These adjustments are (1) rotation of eyeballs controlled by the extra-ocular muscles, (2) change in pupil size, and (3) change in the curvature of the lens. Symptoms of eyestrain in VDT users are burning, watery eyes; heavy, tired eyes; blurred vision and headache.(15)

1. Excessive rotation of the eyeballs

Problem: Most people complain of tired, burning eyes after long periods of working at the VDT station. The extra-ocular muscles controlling the rotation of the eyeballs become fatigued when constantly looking from the source document to the VDT.

Solution: This can be corrected by moving the source document closer to the VDT or placing the document directly in front of the user. To avoid irritation from excessive eye movement, the

VDT screen should be at least 35-40° below a horizontal plane. This permits viewing the visual target in a relatively downward slope of 15-30° from eye level.(9)

2. Change in pupil size

Problem: People complain of irritating sensations to the eyes such as burning, gritty and watery eyes and headache. Eyestrain from excessive pupillary adjustment occurs when looking from a dark display screen to a bright source document or when there is glare from another source of light such as a window.

Solution: Adjust the lighting for the least amount of glare by closing window shades, using nonglare filters or screen hoods and checking the brightness and contrast controls on the display screens. Symptoms from excessive pupillary adjustment are more pronounced in persons over 40 years of age.(9) Proper consideration should be given to each individual for the surrounding lighting conditions. Dimming of the overhead lights, using source document lighting, closing window blinds, and using glare screen protectors all help to reduce eyestrain.

3. Change in the curvature of the lens

Problem: This type of eyestrain is also due to fatigue. Long periods of continual close focusing on material at short distances fatigue the lens muscles of the eyes. A common complaint of VDT users is difficulty seeing or blurred vision and headache.

Solution: Do not automatically assume current eyewear is correct for computer use. Eye exams are advised because glasses prescribed for normal reading distances of about 8-10 inches (0.2m) may not focus clearly. VDT screens exceed distances of 20 inches (0.5m). Bifocals and multifocals further complicate the issue. Viewing objects at chest level or below and at a distance not more than 11-18 inches (30-45cm) seems to work best for people wearing bifocals. Most VDT screens are at face level forcing users who wear bifocals to lean over or hold their head at an extended angle which causes or provokes neck or shoulder pain.(9)

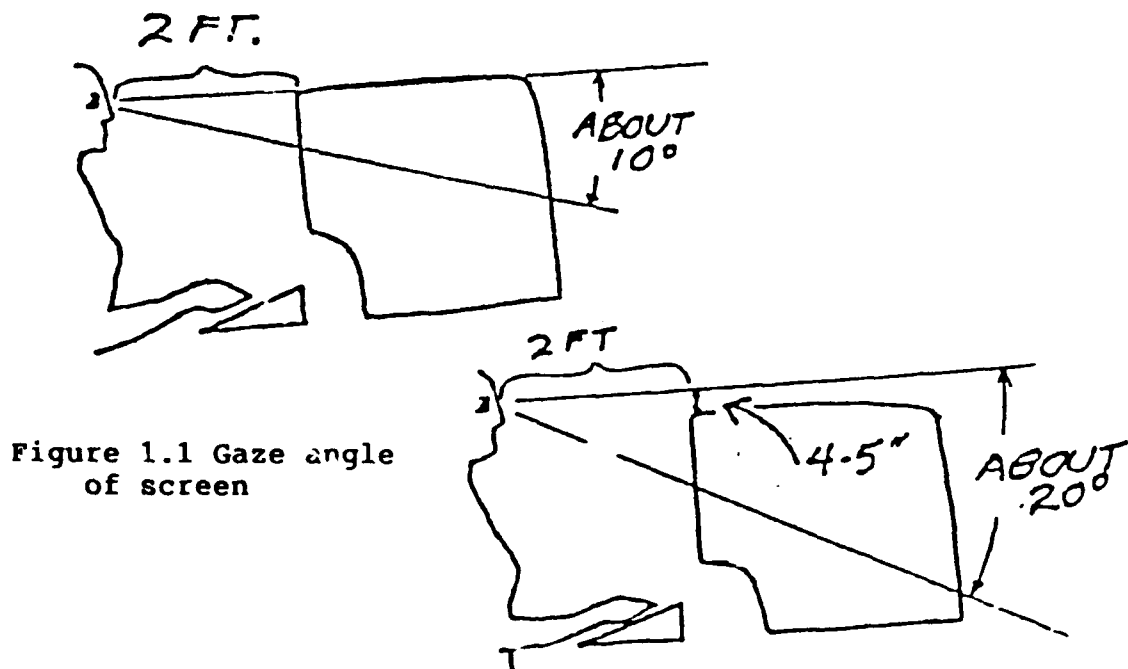
B. Musculoskeletal problems: Stationary work is an important cause in musculoskeletal problems. VDT users remain seated for long periods of time restricting blood flow in the legs. This results in fatigue to the muscles. Among the most common complaints are neck and shoulder pain, backache, arm pain, leg pain and wrist pain. Severe wrist pain is commonly associated with Carpal Tunnel Syndrome (CTS) explained in Section D of this report.

1. Neck and shoulder pain

Problem: Neckache is a common complaint of VDT users. According to a NIOSH study, 81% of VDT users experience some neck or shoulder discomfort.(16) Holding the neck and head in any position for a long period of time will cause fatigue. In the VDT workplace this discomfort is usually caused by a forward head tilt due to a number of factors (unclear characters, visual deficiency of the operator, too great a distance between the screen and operator, and improper angles in the VDT alignments).

Solution: The source document and the VDT should be positioned as closely together as possible to prevent extreme tilts and twists of the neck and head. Make sure the operator has an eye exam and has been prescribed appropriate eyewear for computer use. Legibility problems occur when the distance to the display screen is greater than two feet. The gaze angle should be no more than 20 degrees for most people. At two feet, a 10-degree angle should put the top of the screen a bit below eye level. A 20-degree gaze angle should put the top of the screen about 4-5 inches below the horizontal line of sight (Figure 1.1).(15)

Frequent posture changes and flexible work task movements such as gymnastic exercises relieve neck strain. These can be done by working the shoulder muscles, stretching and bending the body and swinging or turning the limbs. Exercises should be done beside the desk for at least 15 minutes every day. Background music makes the exercising even more stimulating. The results are increased circulation and decreased stress.



2. Backpain

Problem: This is one of the most common complaints of VDT users and is also the focus of most major medical attention. The source of backpain is usually muscle fatigue caused by efforts to hold certain postures for a long time. The human body adopts a slouching position to relieve muscle fatigue thus increasing tension on the vertebral ligaments leading to serious degeneration of the discs and permanent back stiffness and injury. Other causes of back pain are changing of the natural position of the spine, i.e., improper chair and worktable heights, or keyboard too far from the edge of the table. What is the "right" height? Recent research shows the preferred height of the display screen is about 33 to 43 inches from the floor to the center of the screen. The display support surface should be adjustable up to 33 inches. The keyboard support should be adjustable with a low point of 23 inches.(16)

Solution: The proper chair for VDT users should have the following: full backrest with tilt and lumbar support, a chair with adjustable height and proper cushion support. The seat edge must not exert pressure on the back of the thigh when the feet are flat on the floor. The proper worktable should have displays at a height of 33 inches to 43 inches from the floor to the center of the screen. To measure the proper chair height, align a yardstick vertically with the front edge of the chair. With another straight edge held horizontally touching the front top edge of the chair, measure the height on the vertical yardstick from the floor to the bottom of the horizontal yardstick. Press down on the padding of the chair and take a new measurement. Subtract the two measurements to compensate for the seat compression. This will give the effective chair height. Adjust the seat height to this distance and sit down. If there is any pressure on the back of the thighs, lower the chair a bit. The optimum seat height is usually between 16 and 20.5 inches with more variance for very tall or very short people.(15,16)

Trunk inclination (forward or backward tilt of the body) is important to aid in operator comfort. Locate the top of the hip bone and place a straight edge so that it intersects this point and the middle of the shoulder. Measure the angle between the straight edge and the vertical with the backrest tilted all the way forward and then all the way backward. A tilt of 25-30 degrees is desirable.(15,16)

3. Leg pain

Problem: This is a discomfort that has a variety of symptoms that include burning sensation down the back of the legs, aching or heavy-feeling and numbness or tingling in the legs. The causes of these problems are abnormal pressure on the nerves and accumulation of blood in the veins of the legs.

Solution: The best way to prevent leg pain is to avoid long periods of sitting even with the properly designed chair. The most effective break schedule is to rest 10 minutes for each 50 minute work period but more important, is to take breaks before fatigue sets in.(16)

The design of the chair should minimize pressure on the back of the thighs and cushion the buttocks to uniformly support the weight distribution. The front edge of the chair should be rounded down to limit pressure to the back of the thighs. The height of the seat is important in preventing pressure problems. It is important to wear shoes when measuring the height of the chair. Use the same technique as given in the preceding section for measuring chair height.

Next, the chair should be adjusted to the desk until the keyboard and display are at a comfortable working level. Usually the desk is too high and a footrest is needed to compensate for the increased chair height. Use a footrest that is slightly inclined with a nonskid surface. Walking and leg exercises are helpful in counteracting leg and foot swelling. Some personal factors including obesity, pregnancy and constrictive clothing can cause leg discomfort.(15)

4. Arm pain

Problem: Arm pain can be from fatigue which is reversible but in some VDT users, it can mean severe deterioration of bones and tendons or potential damage instead of fatigue. This can lead to serious medical conditions. The fatigue of muscles used to hold the arms and hands outstretched over the keyboard is the most common complaint. Static effort is required to maintain this posture and as a result, steady contraction of the muscles of the upper arms and shoulder-chest region causes fatigue. This will eventually lead to neck and shoulder pain which have already been discussed. Poor hand and arm postures with repeated actions, may cause physical damage to tendons and nerves. Although rare, these problems are serious and will require medical treatment to correct. One problem is arm pain caused by tendon irritation when tendons of the forearm develop small tears at points of insertions on the bones. Another is the superficial irritation caused when the arms and hands become painful from repeated contact with hard or sharp surfaces of the worktable or chair.

Solution: The VDT table should leave enough space in front of the keyboard to allow rest space for the forearms or hands. Well-designed armrests are also important as long as they do not interfere with the user's mobility. The height of the armrest is usually about 9 inches above the low part of the seat between the compressed seat and the bottom of the armrest. The range varies with the individual but is usually between 7-11 inches. The length of the armrest is usually 6-7 inches, measured from the front of the backrest. The armrest should not interfere with the ability to move the chair under the work station. The width of the armrests should be no less than 2 inches and they should be slightly padded. The distance between armrests should be no less than 19 inches.(15,16) Keyboard positioning is very important in keeping the arm-hand alignment as straight as possible. If conventional typing is done, the keyboard should be placed squarely in front of the operator. In single-handed keying, the keyboard is placed off to one side or the other depending on the operator.(15)

5. Wrist and hand pain

Problem: Cramping of the fingers, tingling and soreness of the wrist and hands are common complaints in this category. Muscle fatigue, tendon strains and nerve damage, caused by increased repetitive motions result in wrist pain. Wrist pain is also caused by increased pressure on the median nerve in the carpal tunnel, the area that houses the bones, tendons and median nerve in the wrist. This increase in pressure is caused by repeated ulnar deviation when the wrist bends toward the little finger or when the wrists are bent back in extension.

Solution: The most important concept to remember with preventing wrist pain is to keep the wrist as straight as possible. Wrist rests are commercially available and provide the support needed to minimize the extension (backward bending) of the wrist. A good wrist rest should be a couple of inches wide, padded, and the edge facing the user should be rounded for comfort. A wrist rest can be easily fabricated from a firm piece of foam rubber, shaped and covered with fabric for aesthetic purposes. If the keyboard is broad enough it may be used as a wrist rest.

C. Carpal Tunnel Syndrome: Carpal tunnel syndrome (CTS) is a cumulative stress disorder caused by repetitive motions. The number of cases per year is approximately 23,000.(12) A position of the ulnar deviation is such that the hand is positioned so the little finger is slanted toward the wrist. This causes the carpal ligament to be pulled down and decreases the size of the carpal tunnel, squeezing the median nerve between the ligament and tendon leading to the fingers (Figure 1.2).(13)

Problem: Manifestations of CTS are pain (usually a deep ache), numbness, tingling (in the thumb and three fingers) and weakness in grip, and burning in the wrist and hand as a result of compression or irritation of the median nerve. Atrophy of the thumb muscle is a symptom of a severe level of CTS. Without treatment CTS can lead to marked discomfort, impaired hand function, and in some cases disability.

Solution: Prevention is by far the best way to cope with this problem.(12) To prevent pressure on the median nerve the user should keep the wrist straight, a wristrest and armrest may be helpful. Other precautions include avoiding, backward bending of the wrist, constriction of blood flow from clothing or watchbands or supporting wrist or hands on the edge of the table while typing, repetitive tasks which constrict the muscles and tendons of the hand. If symptoms persist, a physician should be consulted for treatment. The following is not meant to replace a visit to your physician but may identify a CST problem early on before serious permanent damage is done. A simple test, known as "Phalens wrist flexion test," may be performed. Sit, resting your elbows on a flat surface with your forearms in the air. Allow your hands to hang down loosely (similar to a dog begging for a bone) for about one minute. If pain, numbness, or obvious "pins and needles" sensation occur, see a doctor. Another sign is "tingling" which extends to your finger tips when you gently tap the underside of the wrist.

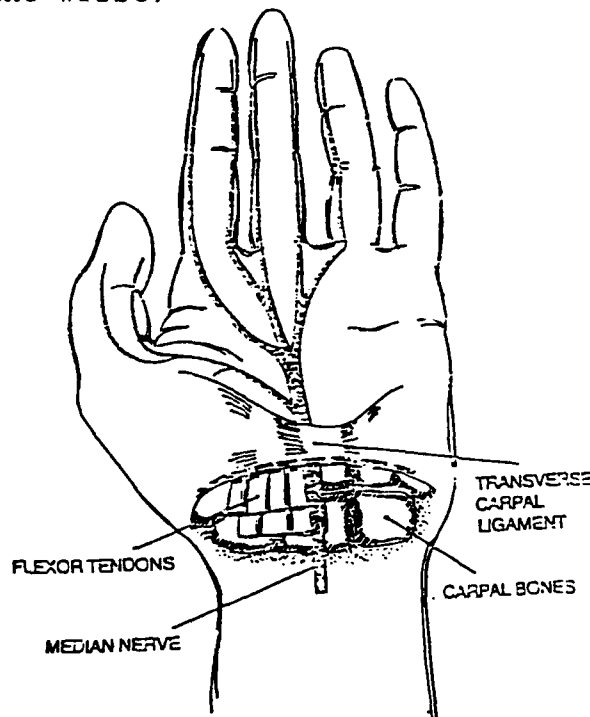


Figure 1.2 Tendons, nerve, ligament and bones associated with CTS

D. Psychological problems: Perhaps one of the most overlooked stress situations in the VDT workplace is psychological strain from the user-system interaction. If the system is slow or has an unfriendly language the psychological stress causes emotional disturbances such as fatigue, tension and anxiety. In a study prepared for the World Health Organization, several issues were addressed that involve the psychological aspects of the VDT user. (10) The most important factors considered were work design and psychosocial conditions.

1. Work design

Problem: Poor design of the VDT workplace is seen first in fatigue and then in the form of emotional stress.

Solution: The easiest way to eliminate this stress is to make sure the worker has access to adequate computer hardware and furniture, i.e., adjustable chairs and computer desks. Correct lighting or methods to prevent glare and training on the VDT use is essential in creating a good working environment.

2. Psychosocial conditions

Problem: The concept of control (or lack of control) of the system is one of the most crucial issues in the mind of the VDT user. Complaints about more "structured" and less choice of working methods seems to be the main issue here. The perception of limited control usually gives rise to stress in the working environment.(10)

Solution: Controllability is a very important issue because it can impact the performance of the man-machine system. A good way to keep the stress down is to let the VDT user have influence in the job design and choice of work demand strategy. Also control over the timing of rest breaks is important in decreasing the stress. Having "control" over these situations helps the VDT user maintain effective variations of very repetitive work.

Problem: Breakdowns, overloading, slow response time and interruptions all can cause frustration for VDT users.

Solution: These problems can be solved at the technological level by reducing the frequency and length of breakdowns. It is wise to have well-trained individuals set up the most efficient systems. Operators should be trained well enough to distinguish between system problems and operator error.

E. Suggested exercises to relieve musculoskeletal discomfort. The exercises discussed below are suggested but other types which work as well may be found in aerobic exercise books. Remember to keep the exercises short. Workers may perform them in their chairs or beside their desk.(15)

1. Back Exercises: The following exercises may help strengthen back and stomach muscles but they are designed to help reverse fatigue and stressful back postures.

a. Pelvic Tilt (conducted in a standing or sitting "sway back" position). Stand with back against flat surface, flatten lower back against wall, hold for few moments; relax and repeat a few times. Once the technique is learned the exercise may be performed in the chair.

b. Back Arch--reverses painful stretching of back muscles and ligaments, and restores the flattened spine to its normal inward curve. Move forward in your chair, place hands on the edge of the chair, straighten up and raise your chest upward and out. Hold this position for a minute or two, relax and repeat.

c. Chair Rock: This mobilizes the spine and promotes the flow of nutritional fluids through the discs. Place feet on the floor and grip the sides of the chair. Rock slowly from side to side looking over the opposite shoulder. Repeat several times.

2. Neck and Shoulder Exercises: These exercises are intended to mobilize muscles that will reverse painful muscle fatigue and momentarily relieve neck stress. These exercises are done from a sitting position.

a. Nose Drawing: Close your eyes move your head and imagine you are drawing a circle with a + sign inside it. Repeat several times. Next, draw an "X" and go over it several times. Try writing your name or figure eights or any object that feels comfortable to you. The key is to do these slowly.

b. Other common exercises are head nods (yes and no head positions), head turns (from side to side), and shoulder circles (extend arms outward from the sides of the body and rotate in a circular motion).

c. Arm stretch: Begin with arms hanging loosely at your sides, head and back straight. Raise the left arm upward over the head and reach towards the ceiling with the right arm reaching toward the floor. Hold, relax, repeat several times, then reverse arms and repeat.

d. Shoulder blade pinch: Move forward in the chair placing hands behind buttocks, be sure to sit erect. Try to touch elbows together behind you, hold, relax, and repeat a few times.

3. Arm and hand exercises: These exercises help to control the discomfort of the hands and forearms. They are easily performed with a short interruption in work.

a. Finger curls: Keep the hand and wrist straight and curl the fingers into a fist. Open the fist, bend fingers upward and stretch. Repeat this cycle one or two times. Return fingers to a neutral position, stretch apart until a slight tension is felt. Remember not to bend hands at the wrist.

b. Palm pushup is an isometric contraction followed by relaxation to relieve tension and stimulate circulation. Place the tops of hands under the front edge of the table. Push with your hands as if trying to lift the table in the air. Now place palms in a similar position on the top of the desk and push down. Drop hands at your side and let them dangle, do not shake but rather wiggle the fingers. Return them to your lap and rest a few minutes. The key is to keep hands flat and do not bend at the wrist.

c. Upper arm relaxer: This stretches and relaxes muscles of upper arm and should relieve tension. Slowly open and spread arms out from your side (pretend your yawning), hold until you feel the tension build in the upper arms. Fold arms back towards you. Hold and repeat a few times. Let arms drop and hang freely at sides for a few minutes.

4. Preventing leg discomfort

a. Foot presses: These reduce leg swelling and should be performed every 10-15 minutes. They may be done without work interruption. Sit erect in the chair, press down alternately with the ball and then the heel of the foot. Repeat several times and relax, alternating feet.

b. Leg reach and toe circles: This exercise mobilizes the major muscles of the thigh and lower leg. Grasp the edges of chair with hands and raise and extend one leg in front of you. Draw a circle in the air while pointing toes

out. Slowly bend knee and raise leg toward chest (about one-third of the way), extend leg again placing it back on the floor. Repeat a few times alternating legs.

F. Suggested exercises for the relief of eyestrain. Eyestrain is not limited to sensations of sore or irritated eyes but is also related to neck and facial muscle tension which may lead to headache and mental fatigue.

a. Relieving soreness (sore or irritated feelings of the eye)--Don't rub the eyes, this only irritates them more. Close the eyelids tightly, hold for a couple of seconds and open as wide as possible. Repeat until relief is felt. Not only does this technique give the eye a thorough message but it stimulates tears to moisten and soothe the eye.

b. Eye muscle stretch: Imagine a snowflake type of pattern on the wall, floor or ceiling at the far end of the workroom. Roll the eye up to the top most point of the snowflake, then down to the lower point. Repeat this movement a few times, then alternate from point to point repeating the movements until the whole drawing is covered. Rest between each set of scans. Do this in a smooth manner and don't make the movements too large.

c. Deep focus relaxes the muscles controlling eye focus. Periodically switch your gaze from the VDT screen to a more distant object (20 feet or more). This causes the muscles to readjust and lessen strain. It is not advisable to do reading or needle point or other forms of close visual work during break periods.

d. "Palming" reduces mental tension. Place cupped hands over the eyes, as in a peek-a-boo gesture. Close the eyes and raise the eyebrows, and think about a pleasant scene.

e. Facial tension is caused from squinting or clenching the jaws. These movements create headache and restrict blood flow. Massage is one way to relieve this type of stress. Place the tips of forefingers and index finger at the top and center of forehead. Slowly separate your hands dragging the finger tips across the forehead exerting firm pressure ending at side of the head. Massage the temples in a circular motion. Return to the center of the forehead slightly below the point where you started and repeat the process. Work down to the eyebrows, massaging the temples each time.

The lower face massage is the same process. Begin at the bridge of the nose, working outward. Return and continue down the sides of the nose working out, massage in small circles below the ears. Allow the jaw to hang loose and don't forget the chin area.(15)

III. CONCLUSION

Complaints of muscle strain, eye fatigue, and psychological stress must be addressed to ensure an effective workplace environment is met. Employees have a responsibility to identify problems, ensure health needs are met and keep themselves in good physical condition. A well-designed workplace lets the users make individual adjustments for improvement (see Figure 1.3).(17) Management must ensure system managers and operators are well trained. This is one of the best ways to reduce psychological stress with VDT use. Rest periods through out the day are also necessary. A number of suggested exercises are designed to relax muscles, improve circulation, and keep the eyes, mind and body refreshed. Improvement of ergonomics in the workplace results in increased employee moral, productivity, and decreased compensation costs.

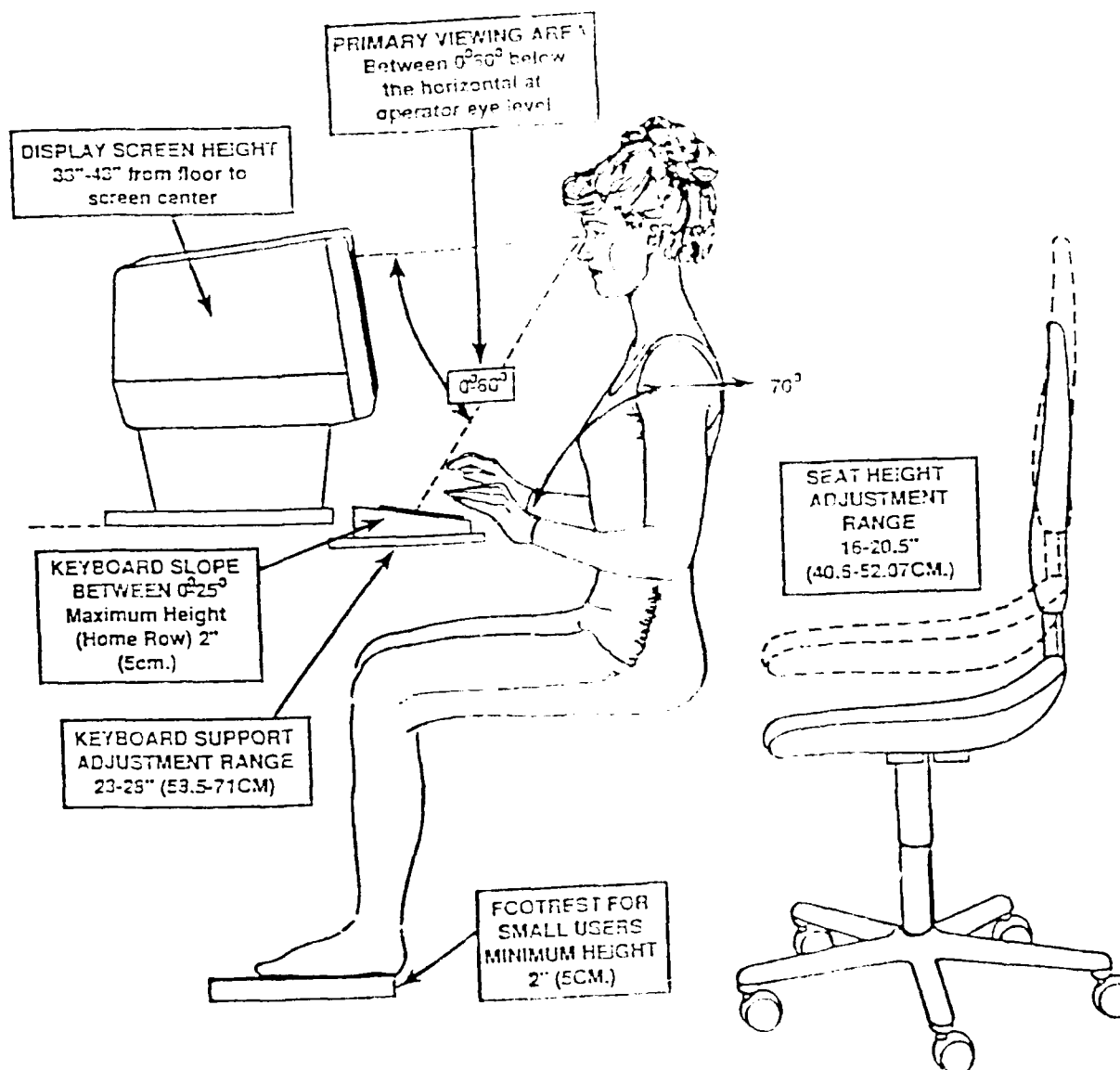


Figure 1.3 A well designed work center

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CHAPTER II

RADIATION FROM VIDEO DISPLAY TERMINALS

I. INTRODUCTION

A. Purpose: This report discusses radiation emitted from video display terminals (VDTs) and the hazards, real and perceived, associated with VDT work.

B. Problem: Approximately 70 million workers in the US and Canada spend part, or all of their workday in front of VDTs.(5) Recently, a lot of attention has been centered on the health effects of VDT work. Among the hazards often associated with VDTs is the radiation they emit. Radiation is often frightening because it is not well understood.

C. Scope: This report will address some basic radiation physics, radiation bioeffects, and the principles of operation of VDTs to try to bring into perspective the hazards of radiation emitted from VDTs.

II. DISCUSSION

A. Physics. Video display terminals, like all electric and electronic devices, emit radiation in the electromagnetic spectrum. This is true because, by definition, the operation of such devices involves the movement of electrons. A fundamental law of physics states that when an electron (or any charged particle) undergoes acceleration (change in direction or velocity), electromagnetic radiation is produced. Time-varying currents, like the alternating current (AC) available at most wall receptacles, cause time-varying electromagnetic fields with the same time variation as the currents that produced them. It is important to understand that these electromagnetic fields are extremely low in intensity unless the conductor carrying the current is the proper size and shape to allow energy to escape; a conductor designed to radiate electromagnetic energy is an antenna.

B. The Electromagnetic Spectrum

1. In the paragraph above we learned that time-varying currents cause time-varying electromagnetic fields. This time-varying characteristic is known as frequency. Frequency is a measure of the number of occurrences (cycles) per second, expressed in Hertz (Hz). One Hz equals one cycle per second. The total range of frequency of the electromagnetic spectrum extends from zero Hz (static fields) to many trillions of Hz. This spectrum includes x-rays and gamma rays, infrared, visible and ultraviolet light, and microwaves and radio waves.

2. By convention, different regions of the electromagnetic spectrum are expressed in different units. Radio frequencies and microwaves are expressed in terms of frequency (Hz), optical radiation (infrared, visible and ultraviolet) are usually expressed in terms of wavelength (in meters) and x- and gamma rays are expressed in terms of photon energy (in electronvolts). Energy of a certain frequency has a unique wavelength and photon energy; therefore, any portion of the spectrum can be expressed in any of these units, but the most convenient units are usually used for each region. Figure 2.1 shows the frequencies of the different regions of the electromagnetic spectrum in all three units.

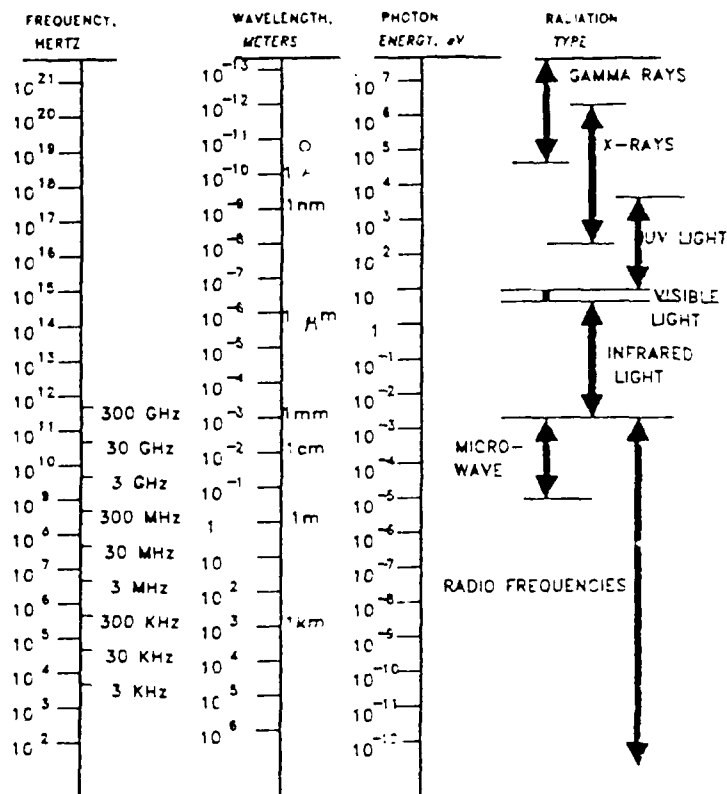


Figure 2.1 The Electromagnetic Spectrum

C. Radiation Bioeffects

1. Radiation in different regions of the electromagnetic spectrum have drastically different effects on the human body. The major division in the spectrum from a bioeffects standpoint occurs in the far ultraviolet region, the commonly accepted dividing point between ionizing and nonionizing radiation.

2. Ionizing radiation (including x- and gamma rays as well as several forms of particulate radiation) is energetic enough to ionize atoms and molecules, creating charged particles (free radicals) within a material. If the genetic material in a cell is ionized, reproduction of the cell can be affected causing cell death or cell transformations. One result of cell transformation is cancer.

3. Nonionizing radiation includes ultraviolet, visible, and infrared light, microwaves, radio frequency waves, very low frequency (VLF) and extremely low frequency (ELF) radiation. Each type of nonionizing radiation has its own set of bioeffects, mostly based on the thermal heating of tissues. These effects are the basis for the current protection standards for this type of radiation.

a. Ultraviolet (UV) radiation is known to cause thermal and photochemical injury to both the skin and eyes. Sunburn (erythema) is the most common effect of UV on the skin. Recent literature has also warned about avoiding prolonged UV exposure because of the risk of skin cancer. UV is absorbed by the cornea and lens of the eye. At high intensities, UV can cause photokeratitis (welder's flash) and cataracts.(19)

b. Visible light stimulates the rods and cones in the retina of the eye. Intense visible light, like that produced by flashlamps, xenon arcs, and visible lasers, can cause flash blindness or thermal lesions on the retina or the skin.

c. Infrared (IR) radiation is divided into two regions, the near-IR (or retinal hazard region) and the far-IR. The near-IR is the wavelength region from 700 nanometers (nm) to 1400 nm. Although near-IR cannot be seen, a majority of the energy does reach the retina of the eye. At high intensities, near-IR can cause burns to both the ocular media and the skin. far-IR (1400 to 10^6 nm) doesn't reach the retina. High-intensity far-IR radiation can cause thermal burns to the cornea of the eye and the skin.

d. Microwave (MW) and radio frequency radiations (RFR) cause damage by heating of tissues. The location of the damage depends on the depth of penetration of the energy into the tissue, which is related to the frequency of the radiation. The current microwave and RFR safety standards contained in AF Occupational Safety and Health Standard (AFOSH Std) 161-9 are lowest for the range of 30 to 300 MHz because these frequencies are the most "effective" at depositing energy into the human body. The effects that have been reported from microwave exposure at high levels include cellular effects, microwave induced cataracts and central nervous system effects. All of these substantiated effects occur at levels ten times the current standard or greater.(11)

e. Very low frequency (VLF) and extremely low frequency (ELF) are electromagnetic frequencies at the lowest end of the magnetic spectrum. ELF includes the frequency of commercial power distribution in the United States (60 Hz). VLF has limited application in communications. The relationship between VLF and ELF radiation and biological effects has not been established; minimal research has been done on effects of VLF and ELF on biological systems. Recently, some epidemiologic studies have suggested that a link may exist between low-level VLF and ELF radiation and biological effects. Studies of power line and power substation workers, as well as electronics technicians and electrical engineers, have been conducted to try to link electromagnetic fields to cancer. These studies produced no statistically significant trends, but the popular press has tried to arouse public interest in the subject through some rather sensational stories.(2) The fact remains that our use of electromagnetic field producing devices (i.e., electric blankets, power lines, household appliances) has risen dramatically in the past 100 years, but the rates of the types of cancer normally associated with radiation have not. Most experts agree that a definitive study is needed to quell the controversy, but they do not expect any link to be established between low levels of ELF and VLF radiation and detrimental health effects.(3,7)

f. Static electricity, although not considered radiation, has been studied in connection with VDT health effects. Static electricity is the build-up of positively charged particles on the VDT screen. This charge sets up an electric field which attracts negatively charged particles and repels positive charges. Theoretically, the charge on the screen and the resulting electric field induce a build-up of negative charges on the operator, which attracts positively charged particles. The result is that particles of dust, molds, or other irritants from the air may be attracted toward the operator's skin. Individuals who are sensitive to certain particles may develop skin rashes as a result of these particles.

To prevent a static build-up, the humidity in the room should be regulated (dry climates have more static electricity), anti-static solutions can be used to clean the screen, and anti-static mats can be used on the floor under the operator's chair.(5)

g. Ultrasound, a non-electromagnetic form of radiation, is also produced by VDTs. Ultrasound, and other frequencies of sound, are created by cooling fans and electronic circuitry. Aside from being an annoyance, the noise from VDTs has no harmful biological effect. Noise levels rarely reach 65 dBA, far below the American Conference of Government Industrial Hygienists (ACGIH) threshold limit value (TLV) of 80 dBA.(20)

D. How a VDT Works

1. VDTs differ greatly in their operation, but most VDTs operate on the same basic principle. An electron beam is focused on a phosphor, causing it to glow. In most VDTs, this operation takes place in the cathode ray tube (CRT), which consists of several elements (See Figure 2.2).

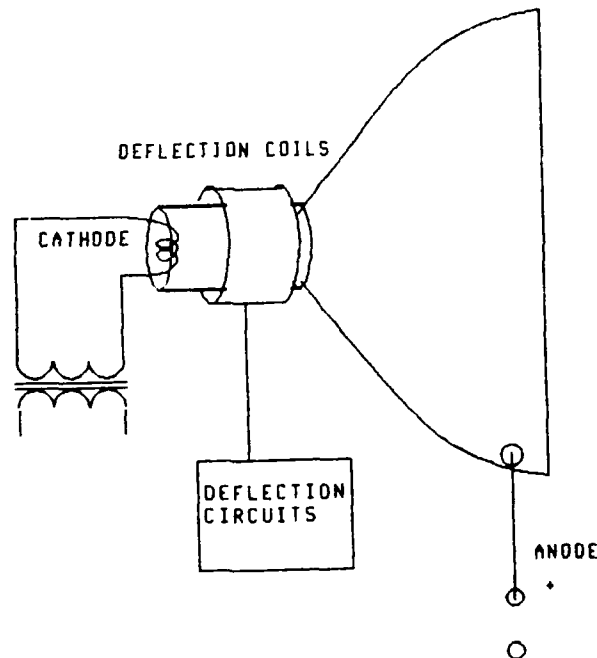


Figure 2.2 Schematic of a CRT

a. The source of electrons for the CRT is called the cathode. The cathode is simply a metal element that, when heated, releases electrons. The released electrons are drawn toward the phosphor by a positively charged element called the anode. The electrons pass through the deflection coils and the focusing coils before they strike the phosphor. X-ray radiation (also known as Bremsstrahlung) is produced by the interaction of the electrons with the molecules in the phosphor. X-rays produced by the 15-20 kV CRT potential are extremely low energy, thus non-penetrating. Code of Federal Regulations Title 21 part 1020.20 establishes emission limits for CRT devices of 10 milliroentgens/hour (mR/hr) at a distance of 30 cm. Measurements of VDTs have demonstrated x-ray levels less than .000003 mR/hr at a distance of 5 cm.(14,21)

b. The glowing (or phosphorescence) of the phosphor is another type of electromagnetic radiation. The wavelengths of light that the phosphor emits depends on the particular type of phosphor. For instance, an amber monochrome screen puts out light at a wavelength of approximately 550 nanometers and a green monochrome screen puts out light at approximately 500 nm. Generally speaking, if the visible light is not too uncomfortable to view, then it is eyesafe. This may not be true if the visible light is mixed with ultraviolet (UV) or infrared (IR) radiation. In those cases, measurements should be made to determine if a hazard exists. Many VDTs also emit some light in the invisible UV and IR regions. Measurements conducted by the Food and Drug Administration (FDA) have shown IR and UV emissions to be far below present safety standards.(6)

c. When electrons are released from the cathode, they are omnidirectional. The anode attracts them toward the phosphor and the focusing coil narrows the beam to a small spot, which is then directed by the deflection coils into specific shapes. Images are formed by sweeping the beam back and forth across the phosphor and rapidly pulsing the beam. After being struck by the electron beam, the phosphor continues to glow for a short period of time. If the images are refreshed (redrawn) often enough, they appear to be continuously present on the screen. Two different bands of nonionizing electromagnetic radiation are produced by the control of the electron beam.

(1) The horizontal scan of the electron beam is caused by the horizontal deflection coils which are supplied to their electronic signals by the flyback transformer. The flyback transformer operates at a frequency of approximately 15 to 20 kilohertz (kHz), resulting in VLF electromagnetic fields which are strongest in the rear of the VDT and drop off dramatically with distance.

Safety standards for VLF have been set at 100 milliwatts per squared centimeter (mW/cm^2) or 614 volts per meter (V/m) by the American National Standards Institute (ANSI), and by AFOSH Std 161-9. Measurements of VLF by various organizations have yielded levels of 170 V/m at the operator position of older VDTs and levels of 25 to 55 V/m from modern VDTs.(6)

(2) The vertical deflection coils operate at a rate of approximately 60 Hz, resulting in ELF fields. Safety standards have not been established for ELF because it has no recognized biological effects aside from electrical shock hazard at very high field levels. Measurements of these fields are extremely difficult and should be suspect unless done by an expert with specific knowledge of ELF measurements.

2. In the past few years, public opinion has forced VDT manufacturers to reduce the emissions of their VDTs. As a result, newer VDTs have much lower emissions than VDTs produced more than 10 or 15 years ago.

E. Pregnancy and VDTs

1. In recent years, a number of clusters of abnormal pregnancies (miscarriages and birth defects) have been reported in VDT workers. The press publicized these as effects of VDT operation, but the epidemiological studies of the clusters yielded no evidence that they could be statistically linked to VDT use. According to the Council on Scientific Affairs for the American Medical Association, approximately 7 million females of childbearing age work with VDTs across the country and the normal miscarriage rate is upwards of 20%, therefore, 50 such clusters of abnormal pregnancies are expected in any three year period.(5)

2. Ionizing radiation protection standards specify separate standards for pregnant female exposures and other human exposures. The standard for non-pregnant adult humans exposed occupationally to radiation limits them to 3 rem (Roentgen Equivalent Man) per quarter (3 months). The standard for pregnant females limits them to 0.5 rem over the gestation period and/or .05 rem/month. The worst case measurements of ionizing radiation from VDTs estimates that an individual who works with VDTs full time (2000 hours per year) gets less than 0.1 rem per year from their VDT.(6)

3. Nonionizing radiation, on the other hand, has no specific effects on the fetus. Protection standards, as a result, are exactly the same for pregnant females as for all adult humans. All measured levels of nonionizing radiation are below any protection standards and therefore not harmful to humans.(1)

III. CONCLUSIONS

A. Levels of radiation emitted from VDTs are well below safety standards. Most of the emphasis on the radiation hazard from VDTs is centered on ELF where no standards exist. While research continues on low level ELF effects, results of studies so far have proven no link between ELF and detrimental effects on humans.

B. Based on radiation effects, no reassignment of pregnant VDT workers is warranted. Stress from radiation worries may be a much greater hazard than any real or imagined radiation itself. All efforts should be made to put the workers at ease about the radiation from the VDTs.

C. No basis exists for recommending radiation control measures for VDTs. As is always the case with radiation, education of the workers is the key to alleviating fears.

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GLOSSARY

Alternating Current	Current in which charge-flow changes direction periodically.
Anode	A positively charged electrode to which electrons are drawn.
Bremsstrahlung	X-ray radiation resulting from the rapid change in velocity of an electron as it approaches, and is deflected by, an atomic nucleus.
Cathode	A negatively charged electrode from which electrons are liberated.
Cathode Ray Tube	A vacuum tube in which a stream of electrons is focused on a phosphor screen to generate images.
Current	The movement of charge.
Electromagnetic Radiation	Energy, propagated through space or a media, in the form of advancing electric and magnetic fields.
Extremely Low Frequency Radiation (ELF)	Electromagnetic Radiation with frequencies in the range of 30 to 300 Hertz.
Frequency	The rate of time variation of any physical quantity.
Hertz	A unit of frequency equal to one cycle per second.
Infrared Radiation (IR)	Electromagnetic radiation in the wavelength range of 0.7 to 1000 micrometers.
Ionizing Radiation	Radiation capable of ionizing molecules.
Microwave Radiation	Electromagnetic radiation in the frequency range of approximately 1 to 300 gigahertz.
Nonionizing Radiation	Radiation incapable of ionizing molecules.
Phosphor	A substance that glows when excited by radiation.

Roentgen (R)	A unit of ionizing radiation based on the radiation's ability to cause ionization in air.
Roentgen Equivalent Man (rem)	A quantity of dose equivalent that expresses on a common scale for all radiations, the irradiation incurred by exposed persons.
Ultrasound	Sound waves out of the range of human hearing.
Ultraviolet Radiation	Electromagnetic radiation in the wavelength range of 100 to 400 nanometers.
Very Low Frequency Radiation (VLF)	Electromagnetic radiation in the frequency range of 3 to 30 kilohertz.
Visible Radiation	Electromagnetic radiation (light) in the wavelength range of 400 to 700 nanometers.
X-ray Radiation	Electromagnetic radiation with photon energies greater than approximately 1000 electronvolts. X-rays are generated in the electron shells of molecules.

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